GLEX-2012.12.2.1x12747

The International Space Station Education Accomplishments and Opportunities

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The International Space Station (ISS) has the unique ability to capture the imaginations of both students and teachers worldwide and thus stands as an invaluable learning platform for the advancement of proficiency in research and development and education. The presence of humans on board ISS for the past ten years has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics (STEM) disciplines which will lead to an increase in quality of teachers, advancements in research and development, an increase in the global reputation for intellectual achievement, and an expanded ability to pursue unchartered avenues towards a brighter future. Over 41 million students around the world have participated in ISS-related activities since the year 2000. Projects such as the Amateur Radio on International Space Station (ARISS) and Earth Knowledge Acquired by Middle School Students (EarthKAM), among others, have allowed for global student, teacher, and public access to space through radio contacts with crewmembers and student image acquisition respectively. . With planned ISS operations at least until 2020, projects like the aforementioned and their accompanying educational materials will be available to enable increased STEM literacy around the world.

Since the launch of the first ISS element, a wide range of student experiments and educational activities have been performed by each of the international partner agencies: National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA) and Russian Federal Space Agency (Roscosmos). Additionally, a number of non-participating countries, some under commercial agreements, have also participated in Station-related activities. Many of these programs still continue while others are being developed and added to the station crewmembers' tasks on a regular basis. These diverse student experiments and programs fall into one of the following categories: student-developed experiments; students performing classroom versions of ISS experiments; students participating in ISS investigator experiments; students participating in ISS engineering education; education demonstrations and cultural activities. This paper summarizes some of the main student experiments and educational activities that have been conducted on the ISS. It also highlights some upcoming projects.

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Introduction

This paper summarizes a variety of the student experiments and educational activities that have been performed on board the International Space Station (ISS) from its first element launch in the year 2000. It begins with a summary of activities accomplished through the year 2011 and active opportunities that are available to students today. The education projects have been conducted and led by the International Space Station Partners – National Aeronautics and Space Administration (NASA), Canadian Space Agency (CSA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA) and Russian Federal Space Agency (Roscosmos).

ISS student experiments and activities have involved schools from all over the world. To date, over 43 million students have participated from over 43 countries, see Figure 1. Students from all across Asia, Australia, Europe, Africa and North and South America including the Caribbean region have had opportunities to be inspired by their involvement in ISS education activities and as a result, have been motivated to pursue careers in science, technology, engineering, and mathematics (STEM).

The projects summarized in this paper represent the enthusiasm to use the ISS as an educational platform. This enthusiasm is shared by university researchers, commercial companies, non-governmental organizations, other international government agencies, students and educators themselves. If the last 10 years of diverse and successful educational activities is any indication of the interest in and excitement for using this unique resource, the era of utilization promises to

Third graders from Sacaton, Arizona tracking the ISS for their EarthKAM project. Image courtesy of Sally Ride Science/EarthKam.

be even more successful. It is clear that, based on the student experiments and activities already completed; the ISS has the exceptional ability to inspire the next generation of thinkers, innovators, leaders and explorers in science, engineering and technology. They will be well-prepared to meet the challenges of tomorrow.

	No. of students	No. of Schools	No. of teachers
Total	43.1M	25K	2.8M

Fig. 1: Student (K-12, Undergraduate and Graduate), School, and Teacher involvement in ISS Education Accomplishments and Opportunities.

I. ISS Education Accomplishments

Some of the most exciting and engaging education activities that have been conducted on the ISS involved living creatures such as butterflies and spiders.

Butterflies and Spiders in Space

The Commercial Generic Bioprocessing Apparatus Science Insert - 03: Spiders and Butterflies (CSI-03) (Education Lead: Stefanie Countryman, BioServe Space Technologies, Boulder, CO) was a scientific investigation that examined the effects of microgravity on the complete life cycle of the *Vanessa cardui*, painted lady butterfly, (egg to butterfly) and the ability of older larvae of a Monarch butterfly species to metamorphosis. Over 170,000 students in grades Kindergarten through 12th grade had the opportunity to compare how the complete life cycle of the butterflies differed in space, when compared to butterflies on Earth. Students also observed the butterflies on Earth in their classrooms and compared them to imagery from the ISS. In addition to the painted lady butterfly, the students studied the Monarch butterfly and an orb weaving spider. Daily images of both the spider and the butterflies were downlinked.

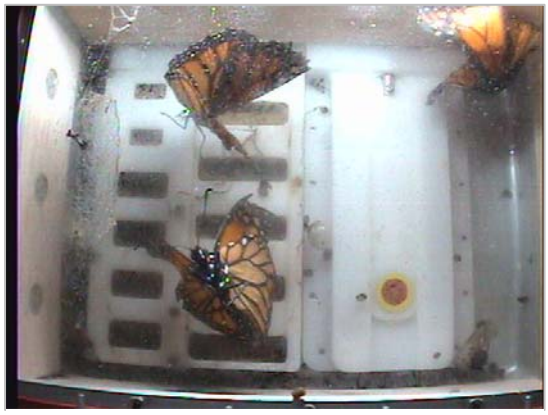

Fig 2: Monarch butterflies in the CSI-03 habitat on board the ISS Expedition 21/22. Image courtesy of BioServe Space Technologies, Boulder, CO.

Kids in Micro-g

The Kids in Micro-g project was an experiment design challenge for students in grades 5 through 8. The purpose was to give young students an opportunity to design an experiment or a simple demonstration that could be performed both in the classroom and on the ISS.

The students were provided a list of materials to use in the classroom that can also be found on board the station. In 2011, the winning experiment, developed by a team of two fifth graders, was titled Attracting Water Drops, which determined if a free floating water drop can be attracted to a static-charged rubber exercise tube. What resulted was an exciting new understanding of physics in space. In a one-gravity environment, a statically charged balloon placed next to a trickle of water will bend the water towards the balloon as shown in Figure. 3.

Fig 3: Statically charged balloon attracts a stream of water. Image credits: Charles D. Winters/Science Photo Library

In microgravity, a tube was rubbed with a towel to create a static charge. The crewmembers then deployed a drop of water in the vicinity of the tube as shown in Figure 4. What was expected was the bubble to be instantly attracted to the tube but instead the drop of water orbited the tube. This was an example of a simple demonstration - developed by ten (10) year olds - with anticipated

predictable results yielding an unexpected discovery.

Fig 4: NASA Astronauts Cady Coleman and Ron Garan perform the Attracting Water Drops experiment from Chabad Hebrew Academy. Image courtesy of NASA.

Tomatosphere

The Tomatosphere program **(**Principal Investigator: Jason Clement, Canadian Space Agency, Quebec, Canada) began in the spring of 2001 and entailed classrooms grades 2 through 10, conducting experiments to investigate the effects of the space environment on the growth of tomato seeds in support of long-duration human exploration. Students compared the rates of germination of the control group and the seeds exposed to the microgravity environment on board the station, see Figure 5. They reported the growth and development of the plants. To date, 13,000 classrooms of students throughout the Canadian region have gotten and continue to have an opportunity to be exposed to space exploration through their involvement with this project. They continue to learn about the effects of microgravity on a potential food source. Students were engage in inquiry on the elements needed to support life in space - such sources as food, water, oxygen and the consumption of carbon dioxide expelled by crewmembers.

Fig 5: Miss Smith's grade three class at Langley Fundamental Elementary enjoyed growing tomato seeds as part of the Tomatosphere program. The students took their plants home to grown in their gardens over the summer.

ISS Education Opportunities

The opportunities for students to be involved in educational activities on board the ISS are endless. There are student competitions, downlinks, education demonstrations and experiments developed by students.

EarthKAM

Earth Knowledge Acquired by Middle School Students (EarthKam) (Principal Investigator: Dr. Sally Ride, Sally Ride Science, La Jolla, CA) is one such activity that engages middle schoolers from across the globe, in ISS image acquisition. Students first identify the targets they would like to photograph, Figure 6. Then with a Nokia camera on the station, students have an opportunity to program the camera to take images of any geographical feature of the Earth. The pictures are downloaded by the students and use curricular materials in subjects such as Earth Science,

Geography, Social Studies and History, to name a few. Since EarthKam is a global project, there has been the involvement of over 175,000 students, 3000 teachers and 2500 schools from 43 countries around the world (see Figure 7).

Fig 6: Students are using computers to help select potential target sites for the EarthKAM camera. Image courtesy of Sally Ride Science EarthKAM.

preparation for the contact, students research topics on space communications and living and working in space. They then prepare a list of questions for the crewmembers about life in space, the ISS and the experiments on board the ISS, or other space-related topics (see Figure 8). Through this experience studetns are inspired to continue their education in STEM fields. Almost 120,000 students from 415 schools in 42 countries

Fig 8: Students attending Space Camp at the Euro Space Center in Belgium are gathered in an auditorium to speak with Astronaut Ed Lu, on board ISS during Expedition 7 in July 2003. Image courtesy of ESA.

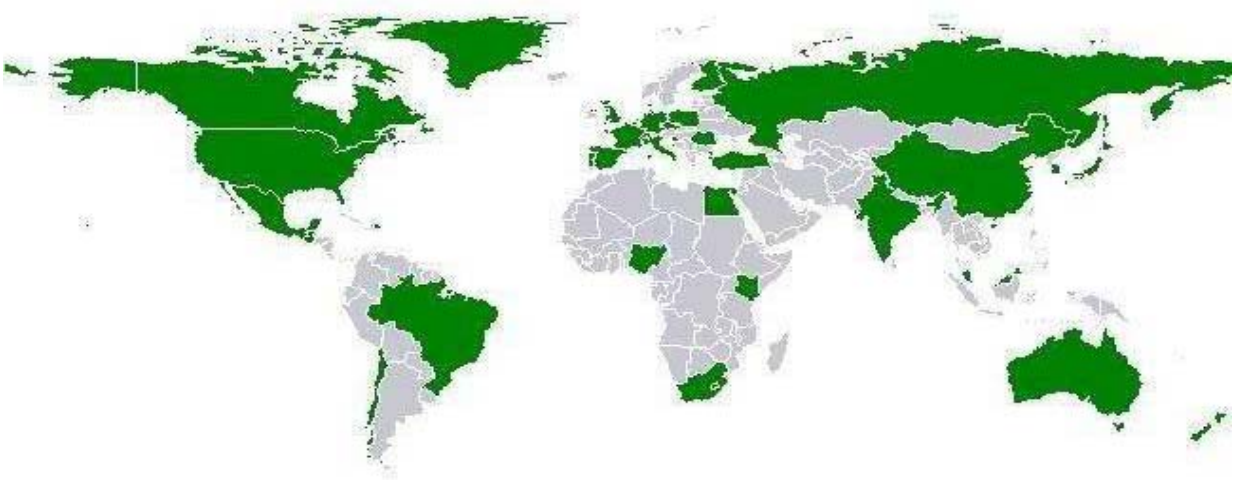

Figure 7: Maps of Countries that participated in EarthKAM missions

International Space Station Ham Radio

The International Space Station Ham Radio also known as ARISS (Principal Investigator: Ken Ransom, NASA JSC, Houston, TX) is another global project that gives students and teachers the opportunity to use ham radio to talk to ISS crewmembers. In

worldwide have participated in the ARISS project.

SPHERES-Zero-Robotics

The Synchronized Position Hold, Engage, Reorient, Experimental Satellites-Zero-Robotics (SPHERES–Zero Robotics) (Principal Investigator: Jeffrey Hoffman and David W. Miller, MIT, Cambridge, MA) is a student competition that involves miniature satellites that are on board the ISS (see Figure 9). College and high school level students have the opportunity to program the satellite to play a challenging game.

Fig. 9: View of the SPHERES floating in the Destiny laboratory module. Image courtesy of NASA.

Student teams that enter the competition are asked to create, edit, share, save, simulate and submit the software code. The winning codes are programmed into the mini-robots on board the station and the crewmembers conduct the championship competition in microgravity with a live broadcast from the station. Students are enormously inspired when they are leading such inquiry-based activities. First conceived by a team at MIT in partnership with NASA, this competition now also involves students from Europe. This was made possible because of an ESA/MIT partnership.

NanoRacks - NanoLabs

Unlike the other education projects that are referenced in this paper, NanoRacks (Principal Investigator: Jeffrey Manbers, Nanoracks LLC, Houston, TX) is a multi-purpose research facility on board the ISS. It is managed under the auspice of the US National Laboratory, which is a portion of the ISS designated by Congress to be utilized by the commercial, academia and non-profit sector and by other government agencies.

NanoRacks provides 'Plug and Play' microgravity research facilities that allows small standardized payloads to be plugged into any of the platforms, providing interface with the ISS power and data capabilities. NanoRacks offers flight opportunities K-12 schools and universities to conduct student-developed experiments that are designed to examine the effects of microgravity on various physical, chemical or biological processes. In January 2011, Valley Christian High School of San Jose, CA was the first high school in the nation to undertake a commercial project when they flew plant seeds on board the space station. This project serves as a trailblazer opening up the ISS National Laboratory as a commercial space STEM provider.

Valley Christian High School students designing NanoRacks-VCHS Plant Seed ISS payload. Image courtesy of NanoRacks LLC.

Conclusion

At its core, the International Space Station education portfolio strives to allow for participation in support of the ISS mission by the world-wide public, educators and students. Consistent with the goals of each of the ISS Partner Education offices, projects continue to be developed that promote the STEM fields with the expected outcomes of (1) motivating and inspiring the next generation of scientists, engineers, technologists and mathematicians, (2) attracting and retaining students in STEM disciplines through a progression of education and research opportunities for students, formal and informal educators, (3) identifying opportunities to extend the impact of STEM educational activities to reach more students and (4) building strategic partnerships and linkages that promote STEM literacy through formal and informal educational opportunities. In so doing, the ISS program serves as an educational resource for students, educators and life-long learners through the lifespan of the station.

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